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THESIS

EVALUATING ARMY BASES' ABILITY
TO SUPPORT MANEUVER TRAINING:
A LINEAR PROGRAMMING APPROACH

by

Wesley G. Gillman

September, 1993

Thesis Advisor: Robert F. Dell

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REPORT DOCUMENTATION PAGE	Form Approved OMB Np. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE September 1993	3. REPORT TYPE AND DATES COVERED Master's Thesis

4. TITLE AND SUBTITLE EVALUATING ARMY BASES' ABILITY TO SUPPORT MANEUVER TRAINING: A LINEAR PROGRAMMING APPROACH	5. FUNDING NUMBERS
6. AUTHOR(S) Wesley G. Gillman	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey CA 93943-5000	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.	12b. DISTRIBUTION CODE

13. ABSTRACT *(maximum 200 words)*

The United States Army is facing a significant challenge to maintain the training readiness of its force. The supply of training land has not significantly increased since the end of World War II; whereas the demand for training land has substantially increased due primarily to an increase in the size of the force stationed in the Continental United States (CONUS) and improved technologies demanding larger areas for effective training. This thesis develops and solves a linear programming model that evaluates the "military value" of a CONUS Army installation's ability to train stationed units. The model determines what percentage of units can perform required maneuver training, what is the reduction in land size required to allow required maneuver training to be performed, what is the impact of reducing the number of days training areas are available, and what is the impact of increasing the number of stationed units. The model was used for an extensive study of Fort Hood, Texas and indicates only 84% of the required maneuver training can be achieved using the current requirements. All required maneuver training can only be accomplished when some units are assigned only 40% of the required amount of land. When the number of days available for training is reduced by two-thirds, the percentage of required maneuver training accomplished decreases from 84% to 75%. For the 1998 increased number of units at Fort Hood, the percentage of required maneuver training performed again drops to 75%.

14. SUBJECT TERMS Maneuver Training, United States Army Training, Training Circular 25-1, Base Realignment and Closure, Fort Hood	15. NUMBER OF PAGES 65
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89)

Prescribed by ANSI Std. 239-18

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Evaluating Army Bases' Ability
to Support Maneuver Training:
A Linear Programming Approach

by

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Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

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ABSTRACT

The United States Army is facing a significant challenge to maintain the training readiness of its force. The supply of training land has not significantly increased since the end of World War II; whereas the demand for training land has substantially increased due primarily to an increase in the size of the force stationed in the Continental United States (CONUS) and improved technologies demanding larger areas for effective training. This thesis develops and solves a linear programming model that evaluates the "military value" of a CONUS Army installation's ability to train stationed units. The model determines what percentage of units can perform required maneuver training, what is the reduction in land size required to allow required maneuver training to be performed, what is the impact of reducing the number of days training areas are available, and what is the impact of increasing the number of stationed units. The model was used for an extensive study of Fort Hood, Texas and indicates only 84% of the required maneuver training can be achieved using the current requirements. All required maneuver training can only be accomplished when some units are assigned only 40% of the required amount of land. When the number of days available for training is reduced by two-thirds, the percentage of required maneuver training accomplished decreases from 84% to 75%. For the 1998 increased number of units at Fort Hood, the percentage of required maneuver training performed again drops to 75%.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

This thesis develops a linear programming model which determines the "military value" of a United States Army installation's ability to support stationed unit maneuver training. An extensive study of Fort Hood, Texas demonstrates the model's capabilities (although the model could be easily used for any installation).

When using Army manuals, the current inventory of units at Fort Hood, and the actual training land at Fort Hood, results indicate that only 84% of the required maneuver training can be achieved. In order to have all of Fort Hood's units accomplish all of their required maneuver training, some units have to accept only 40% of the required land size. When the number of days available for training is reduced (perhaps due to environmental conditions) from 365 days (year round availability) to 250 days , the percentage of required training performed decreases from 84% to 75%. For the scheduled 1998 increase in the number of units at Fort Hood, the percentage of required training performed again drops to only 75% of the current required levels.

This linear program was developed in response to the United States Army's challenge to maintain the training readiness of its force. The supply of training land has not significantly increased since the end of World War II; whereas the demand for training land has substantially increased primarily due to an increase in the number of units in the Continental United States (CONUS) and improvements in technology making it possible for today's combat

forces to affect the actions of its adversaries at much greater ranges than was ever before possible.

These factors coupled with the Army's closing of military bases, creates a need for optimal use of existing lands. The linear program developed in this thesis provides a tool to both determine optimal unit stationing and unit maneuver training.

I. INTRODUCTION

The United States Army is facing a significant challenge to maintain the training readiness of its force. The supply of training land has not significantly increased since the end of World War II; whereas the demand for training land has substantially increased due in part to [Ref. 1:pp. 1-1 - 1-7]:

- An increase in the number of units in the Continental United States (CONUS),
- Improved technology increasing the ranges at which one can see, engage and kill the enemy. The average World War II battlefield, 4890 acres (19 square kilometers), compares to a modern battlefield of 80,000 acres (311 square kilometers) [Ref. 2:p. 1C],
- Training to support Army doctrine, "The Airland Battle Doctrine" hinges upon the need for mass, speed and maneuver, actions that can only be performed in large areas.

These factors, coupled with the Army's closing of military bases, creates a need for optimal use of existing lands. This thesis develops a linear programming model which evaluates an Army installation's ability to train stationed units in accordance with requirements for unit maneuver training (UMT) and training land availability.

A. ARMY TRAINING

The United States Army's primary purpose is to defend the country. Overall the Army must be [Ref. 3:p. 3]:

- Trained to fight as a Joint or Combined Force,
- Versatile,
- Deployable,
- Expansible,
- Capable of Decisive Victory.

To ready itself capable, the Army conducts rigorous training exercises which mimic tasks it needs to perform in the event of hostilities.

Training exercises comprise various training missions each of which involves a strict regimen of tasks. Most of the tasks require land in which to train or to maneuver and this thesis concerns itself with this form of maneuver training. To keep the environment or conditions realistic to simulate actual combat, the Army strives to get the amount of land needed to conduct this spatial aspect of training. As General Paul Schwartz, the former Deputy Corps Commander at Fort Lewis, Washington stated; "War is a science where you pass or fail depending on the standards of training." [Ref. 2:p. 1C]

Standard conditions for training exercise tasks are found in Mission Training Plans (MTP). The type and frequency of which missions to train, as well as the amount of land required to perform these missions are usually listed in training circulars. For example, Training Circular (TC) 25-1, *Training Land* lists the requirements for all units contained in a Heavy Mechanized Division [Ref. 1:pp. A-6 - A-21].

1. TC 25-1, *Training Land*; The Requirements

The Army assures itself of standardized training through the use of training circulars such as TC 25-1. From Appendix A of TC 25-1, the following information is listed:

- type of unit (Infantry, Armor, Field Artillery, Air Defense, Engineer, Maintenance, Signal, Military Police, Transportation, Military Intelligence),
- size of unit (battalion, company, platoon),
- required missions to train,
- size of the land needed to perform required missions,
- number of iterations required,
- number of days required to train each iteration.

With these requirements, the Army ensures that the majority of units are able to perform the same missions. Consequently, when units combine into a force similar to that assembled for Operation Desert Storm (ODS), units can fight together in an effective manner.

2. The Importance of Training Land

ODS showed the type of maneuvering capability that the Army needs. General Schwartz spoke on the "bottom-line" importance of training land by stating; "People believe the Army trains by marching in quadrangles and somehow magically acquires the skill on the spot when it goes to fight." [Ref. 2:p. 1C] He continued by saying: "That's not how it works, you train your butt off for long periods of time." [Ref. 2:p.

1C] To perform in the manner that the Army did in ODS, the Army needs space to train.

B. AVAILABILITY OF TRAINING LAND

The Army currently controls approximately 11.2 million acres on 208 installations [Ref. 4:p. 1C]. However, not all of the 11.2 million acres is suitable for UMT. Much of the total area under the Army's control is used for housing, administrative and control centers, and supply depots. Of the remaining acreage, much of the land is used for live fire training and impact areas. Other land is geographically unfit for maneuvering units since they require land that both simulates conditions of potential conflicts and provides space to move across the terrain. Maneuver units (usually possessing "tracked" vehicles) do not train in rugged or swampy terrain and they are not likely to operate in this type of terrain in combat.

1. Limits On Available Land

The goal for Army installations is to have as many of their stationed units as possible undergo required training without having to decrease the standards or the requirements for training [Ref. 1:p. 1-7]. As the Army continues to realign and restructure, Army installations in CONUS are ending up with a much greater density of units than before the end of the Cold War [Ref. 2:p. 1C]. This not only increases the demands on the available CONUS land, but also causes related problems in the environmental community. Environmentalists show concern about Army training lands receiving excessive damage from overuse by tracked vehicles [Ref. 5:p. 1]. This problem is expected to become significant due to returning units from Europe [Ref. 2:p. 1C].

From the Army's standpoint, maintaining the current level of usable acres is critical to maintaining its ability to train. Attempts within the past few years to get more land have failed.

2. Inability to Acquire More Land

The Army requested an additional 265,700 acres for maneuver training at the premier CONUS training facility, the National Training Center at Fort Irwin, California. However, this request was put on hold by the Government Accounting Office (GAO). The GAO said the Army must place more emphasis on activities like simulations that will decrease their demands for training land [Ref. 2:p. 1C]. Other obstacles exist to keeping current Army land. Grace Bukowski, coordinator for Citizen Alert, a Nevada based coalition that monitors government land use said [Ref. 2:p. 1C]:

> We're saying if you need a place to train, tell us what you need. Until you prove (that) you don't have enough, you're not going to get anymore.

Herein lie the challenges that the Army is attempting to meet. Specifically, one can categorize the Army's challenges into three areas:

1. Maintain and preserve the current inventory of training land,

2. Find an optimal level for training with existing inventories by adjusting or reducing requirements(i.e., possible adjustments could be made to the number of units stationed at an installation, number of days and/or iterations required, number of missions required for training, size of land required for missions),

3. Use additional means (i.e., linear programs, simulations, scheduling models, research) to justify the need for additional training land.

C. OVERVIEW OF THESIS

This thesis develops and solves a linear programming model that evaluates the "military value" of a CONUS Army installation's ability to train its stationed units with available training land. As previously stated, there is a shortage in the supply of available training land and the demand continues to rise. This study is designed to assist in identifying current and projected capability. In general, the goal is to obtain a value, the military value, for an installation's ability to support its stationed units' maneuver training. Specifically, the issues and questions that this thesis addresses are:

1. What percentage of units can train under the current requirements and the current availability of training land? For situations where all units can not train, what is an acceptable reduction in land assigned compared to land required for training missions (heretofore referred to as land used/land required) in order to have the majority of units conduct required training?

2. What level of land used/land required is needed in order for all units to accomplish required training?

3. What is the impact on unit training frequency when the number of days that training land is available is decreased?

4. What is the impact of increasing the number of units currently required to train at an Army installation?

This thesis addresses these issues in the following manner. Chapter II lists and discusses current Army models and software that are related to this thesis. Chapter III presents a linear programming model that can be used to study the problem. Chapter III also provides all of the relevant variables, data, and measures of effectiveness used in the model. Chapter IV introduces a test case - Fort Hood, Texas - and provides results. Chapter V presents conclusions and ideas for expansion. Appendices A and B are tables of data specific to Fort Hood. Appendix C contains representative samples of the reports that the model generates.

II. PREVIOUS ARMY LAND USE RESEARCH

A. RELATED ARMY MODELS

Three existing Army models are directly related to this thesis:

- Army Training Land Assessment Model (ATLAM)
- Range Facility Management Support System (RFMSS)
- Integrated Training Area Management (ITAM)

These models are not entirely independent of each other; however, for the purposes of discussion they are handled individually. In the following section, each model is discussed with attention to their shortcomings as they relate to this thesis. In summary, none produce an overall military value and only one evaluates the effect of lessening training requirements.

1. ATLAM

ATLAM is primarily designed to determine whether or not a shortfall of training land exists. The model, covered extensively in TC 25-1, is based on an acre-day approach to unit training [Ref. 1:pp. 3-2 - 3-9]. As the name implies, one acre-day is any product of acres and days that produces one (i.e., one acre times one day or one-half acre time 2 days both produces one acre-day). Given the specific requirements listed for various units, a sum of all needed acre-days is produced. If total acre-days required is less than the amount available, ATLAM is terminated. If a shortage exists, ATLAM results are used as a justification to initiate a request for more land.

ATLAM is not designed to address all the issues of concern in this thesis. ATLAM only considers the total acre-days available at an installation. The concept of "acre-days" allows any combination of available acres and days that produce the same value to be counted equally. The model in this thesis includes separate unit requirements for both land and days. ATLAM also considers each piece of land at an existing post equally, thus saying that all units can train effectively in any location. This is not the case. Combat elements such as mechanized infantry or armor battalions can not effectively train in heavily wooded or in hilly terrain. ATLAM possesses the ability to adjust unit requirements to satisfy required unit maneuver training; however, this has to be performed manually and may have to be repeated an infinite number of times. Lastly, ATLAM ignores any priority for specific units, missions or the type of area considered for training.

2. RFMSS

RFMSS is designed to automate the process of scheduling units to maneuver areas and live fire ranges [Ref.

6:p. 3]. RFMSS is a spreadsheet that holds reservations for requesting units. In place at over 50 installations in CONUS, RFMSS relies on support personnel to update the data base of available land. As a spreadsheet, RFMSS also ignores priority of some units over others and proclaims that priority issues need to be resolved at the unit level. This model does not produce an overall result which indicates an installation's ability to support training.

3. ITAM

ITAM is a comprehensive training land management program fielded to address land management problems [Ref. 7:p. 161]. ITAM objectives are to:

- Establish a long-term natural resource and land inventory, monitoring, and trend analysis program designed to evaluate training land capability.
- Interface land capability and rehabilitation actions with training requirements to promote long-term mission support.
- Establish an environmental awareness program that encourages stewardship and wise tactical use of installation natural resources.
- Provide multi-purpose land rehabilitation and maintenance/erosion control techniques that optimize soil stabilization at minimum cost and time, and provide a more realistic and useful environment for training.

ITAM is the overall program that encompasses additional programs such as Land Condition Trend Analysis (LCTA) and Training Requirements Integration (TRI)[Ref. 7:pp. 161-162]. ITAM also incorporates the use of a huge data base that is part of the Geographical Resource Analysis Support System (GRASS) [Ref. 1:p. 4-6].

ITAM monitors the availability of all training areas at an installation, but it does not consider the size of land required for training missions. ITAM does not produce an overall indication or military value of an installation's ability to support its units in all their training requirements.

B. A NEED FOR A REFINED MODEL

In order to address the Army's challenges to the specific training land problem addressed in this thesis, the three previously discussed models could not be used without extensive human intervention. A model is needed that gives a solution which shows the degree an installation can support UMT and that allows for a variation in requirements (i.e., land required) to achieve an optimal level of this training.

The three previously mentioned models however could assist this thesis process by identifying additional constraints on the use of land. This assistance is in the form of reporting how often certain training land is not available. RFMSS traditionally carries such information when it is faithfully used; however, many installations are only recently beginning to put enough emphasis on environmental factors to place training land off limits.

III. A MODEL TO EVALUATE TRAINING SUPPORTABILITY

A. INTRODUCTION

This chapter formulates a linear programming model that evaluates the military value of a CONUS Army installation's ability to train its stationed units using available training land. Additionally the model is able to vary critical parameters that could improve overall UMT frequency. By lowering levels on required land size, number of days, and/or iterations the tradeoffs needed to obtain greater percentages of required training are determined.

Because training land is traditionally referred to as "training areas" on military installations, the remainder of this paper will utilize the latter reference. Additionally, references to "unit training" or "training" refer to the UMT that is the focus of this thesis.

1. Objective of the Model

The objective of the model is to maximize the number of iterations units train subject to a minimum level on iterations and size of training area needed. Training frequency limitations due to training areas are as follows:

- Days available,
- Type of terrain,
- Competition among units.

Training frequency is further constrained by the following requirements on unit training activities:

- Amount of land used within a training area,
- Number of days per iteration required for each training mission,
- Number of iterations for each training mission,
- Type of training mission.

The frequency of unit training is weighted by a user defined "benefit" factor. Summing the number of weighted iterations with a penalty for failing to train to the minimum level required produces the overall military value.

2. Assumptions of the Model

In order to physically model the units and the training areas at an installation, a number of assumptions are made. The following assumptions prevail through model development and analysis of the results:

- The model assigns units to specific training areas and ensures the total number of days these training areas are used does not exceed their availability; however, the model does not attempt to schedule or allocate units to specific training locations on a specific day. Chapter IV includes a discussion of how to produce such a schedule from the resulting solution,
- Since producing a schedule is not an objective, the results of the model may show units performing consecutive iterations whereas in reality training iterations of this nature are spread out over the course of a fiscal year,
- Since the model hinges on the assignment of priorities for various units to train(i.e., the "benefit" coefficient), it is assumed that this issue of prioritization could be obtained from local authorities.

3. Modelling Training Areas

Training areas are represented in the model as Major Training Areas (MTAs) and divisions. For purposes of the model, what installations refer to as "training areas" are grouped and categorized as MTAs. MTAs are modelled in accordance with two primary features:

- Contiguous training areas, where the total MTA acreage is connected,
- The MTA's ability to support tracked vehicle movement. If an MTA can support tracked vehicles it is classified "GO" terrain. MTA's not able to support this movement are classified "NO GO." MTA's falling into a partial movement possible category are classified as "SLOW GO."

Divisions are the MTA divided into different sizes. The model optimally determines the number of days different divisions of each MTA should be reserved to support unit training. MTA divisions are referred to as D"X" where the "X" is an integer corresponding to the number of divisions. For example, Figure 1 shows how a MTA is divided. Division "D1" implies the MTA is not divided. A division "D2" is when the MTA is split in half and each piece used by a unit equals one-half of the original MTA size.

The training areas in the model are continually broken down in the manner represented in Figure 1 until the sub-divisions become too small to support a specific unit's type of training. Of course, the total amount of time the area is in use across all divisions can not exceed the amount of time

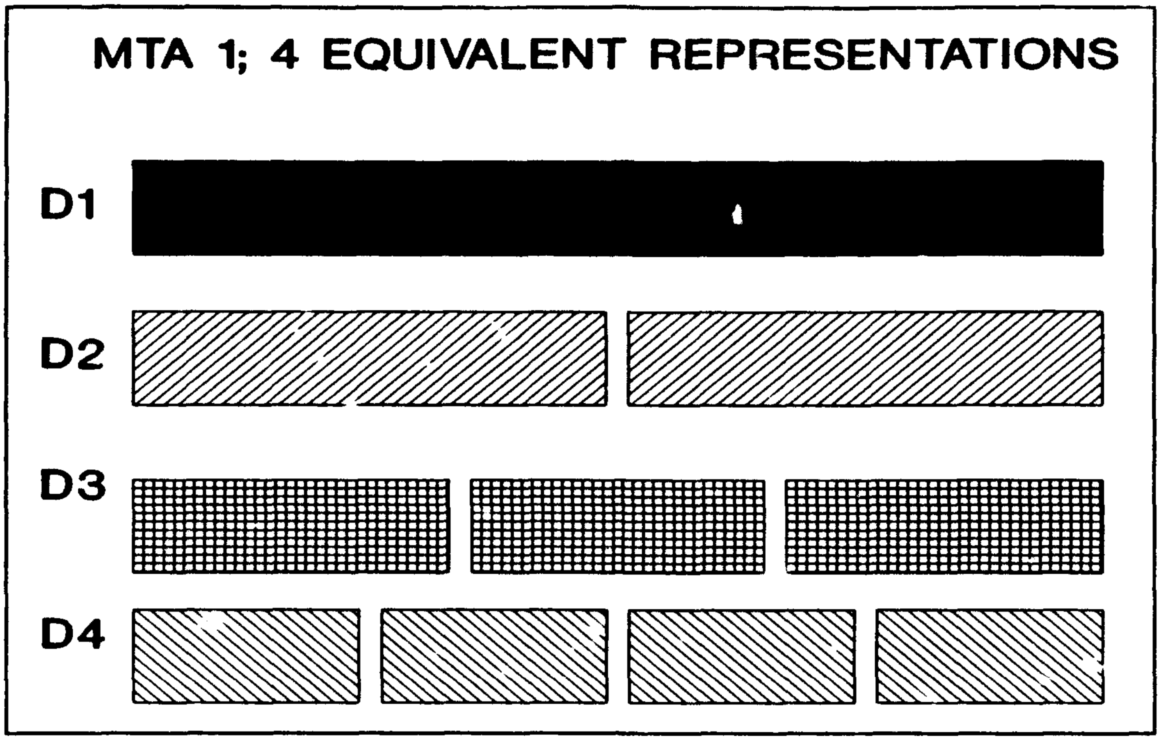

Figure 1 MTA Representation in the Model. MTAs are formulated by dividing the original size of the land into smaller pieces. For example, a "D1" corresponds to the whole MTA and "D4" implies the MTA has 4 divisions.

the MTA is available.

B. THE MODEL

The model follows after introduction of appropriate notation.

1. Indices

b battalion number/designation (BN1,BN2,BN3-1,BN3-2,BN4,BN5,BN6,BN7-1,BN7-2,BN8,. .,BN18);

u unit designations: (B for battalion, C1,C2,..C4 for companies, P1, P2,...,P7 for platoons);

m training mission;

a MTA;

d divisions;

l level of training over the minimum required.

2. Data

$DAYAVAIL_a$ number of days that MTA a is available;

$DAYS\_REQ_{bum}$ days required for battalion b's unit designation u to train for mission m;

MIN_REQ_{bum} minimum number of iterations required for battalion b's unit designation u to train for mission m;

$BENEFIT_{bumad}$ benefit for being able to train one battalion b's unit designation u on mission m in MTA a's division d;

DE_VALUE_{bumadl} a portion of the benefit that is penalized in the model for allowing battalion b's unit designation u to overtrain level l iterations on mission m in MTA a's division d;

DEV_PEN penalty assessed for any unit not performing the required training iterations.

3. Decision Variables

X_{bumad} number of times battalion b's unit designation u trains mission m in MTA a's division d;

R_{buad} number days reserved for battalion b's unit designation u to train in MTA a's division d;

$OVER_{buml}$ number of times that battalion b's unit designation u overtrains at level l on mission m;

DEV_MIN_{bum} number of iterations which battalion b's unit designation u deviates from the minimum mission m training requirement.

4. Formulation

max

$$\sum_{b}\sum_{u}\sum_{m}\sum_{a}\sum_{d} \left[(BENEFIT_{bumad}*X_{bumad}) - \left(\sum_{l} DE\_VALUE_{bumadl}*OVER_{buml}\right) \right] - \left[\sum_{b}\sum_{u}\sum_{m} (DEV\_PEN*DEV\_MIN_{bum})\right]$$

$$\sum_{m} (DAYS\_REQ_{bum}*X_{bumad}) \le d * R_{buad} \qquad \forall\, b,u,a,d \qquad (1)$$

$$\sum_{b}\sum_{u}\sum_{d} R_{buad} \le DAYAVAIL_{a} \qquad \forall\, a \qquad (2)$$

$$\left(\sum_{a}\sum_{d} X_{bumad}\right) - \left(\sum_{l} OVER_{buml}\right) \le MIN\_REQ_{bum} - DEV\_MIN_{bum} \qquad \forall\, b,u,m \qquad (3)$$

The objective function maximizes the sum of iterations performed, weighted according to a "benefit" coefficient. Two penalties are subtracted for failing to train to the minimum level required (DEV_PEN) and for training over the minimum level (DE_VALUE_{bumadl}). The penalty for overtraining serves to reduce the benefit awarded and accounts for the view that training over the minimum is not as valuable as training up to the minimum.

Constraints (1) and (2) ensure that the number of days each MTA is used in its different divisions does not exceed the total number of days available. They also ensure that a battalion's training as a platoon, company, and battalion does not take place simultaneously. These constraints enforced in a less restrictive manner, Equations (4) and (5):

$$\sum_{b}\sum_{u}\sum_{m} (DAYS\_REQ_{bum} * X_{bumad}) \leq d * R_{ad} \qquad \forall\, a,d \qquad (4)$$

$$\sum_{d} R_{ad} \leq DAYAVAIL_{a} \qquad \forall\, a \qquad (5)$$

allow a soldier in a battalion to be assigned simultaneous training in his battalion, his company and his platoon.

The last constraint, equation (3), requires unit training iterations (UTI) to either meet, exceed, or deviate from the minimum.

C. PLACING A VALUE ON UNIT TRAINING

The general framework of the linear program's objective function consists of a benefit for each iteration of unit training up to the minimum required number of iterations. The benefit can vary for specific unit, mission, and land assigned. A method of obtaining the $BENEFIT_{bumad}$ coefficient is described below along with the rationale for its development.

1. Performing Required Training

For the purposes of this thesis, the coefficient $BENEFIT_{bumad}$ is a function of the following:

- A priority for training unit sizes (e.g., platoons before companies or companies before battalions), included since local commanders at different installations may have differing measures of importance,
- A ranking for one mission being more important than the others; for example some units may receive orders to begin

training for a "real-world" mission that they had not otherwise trained for,

- Units preference for specific training areas (e.g., combat battalions require training areas in which to maneuver, while combat service support would prefer more covered terrain where they can remain under camouflage or maintain their more common "stagnant" field positioning).

These factors are combined to form "$BENEFIT_{bumad}$" as follows:

$$BENEFIT_{bumad} = (BEN\_BU_{bu} + BEN\_BM_{bm} + BEN\_BMA_{bma}) * BEN\_O_{bumad}$$

where:

BEN_BU_{bu}	benefit for training battalion b's unit designation u;
BEN_BM_{bm}	benefit for training battalion b on mission m;
BEN_BMA_{bma}	benefit for training in MTA a with battalion b on mission m;
BEN_O_{bumad}	the minimum of either 1, or the ratio of land used to land required.

These parameters represent priorities assigned based on the battalion and unit (BEN_BU_{bu}), the mission (BEN_BM_{bm}), and the MTA (BEN_BMA_{bma}). It is possible to prioritize each of these by using an ordinal scale. For example, if the local commander wants to give training area priority to combat elements and to the smallest unit size platoon, one possible scale for BEN_BU_{bu}, which is used in all computational reports in this thesis, is shown in Figure 2.

CATEGORY OF BATTALION	SIZE: BATTALION	SIZE: COMPANY	SIZE: PLATOON
COMBAT	9	12	15
COMBAT SUPPORT	6	7	8
COMBAT SERVICE SUPPORT	1	3	6

Figure 2 Assignment of Benefit for Type and Size of Unit. The benefit for a battalion, company, or platoon within an Army combat, combat support, and combat service support battalion is defined by the user.

A similar ordinal scale is used to assign a magnitude to the parameter BEN_BM_{bm} once the determination has been made concerning the relative importance of each mission.

Determination of BEN_BMA_{bma} is made while considering the maneuverability category of a MTA. A traditional way to classify a MTA's "maneuverability" category is to determine whether the MTA is "GO", "SLOW-GO", or "NO-GO" terrain:

- "GO" terrain is highly maneuverable terrain preferred by all units; however is normally given to combat units (Infantry, Armor, Field Artillery);
- "SLOW-GO" terrain is medium maneuverable terrain where combat units would incur difficulty maneuvering. Other units such as the combat support or combat service support (such as medical or maintenance units) could use this terrain without significant impact on the training;
- "NO-GO" terrain is terrain where maneuverability by certain Army units is impossible, and only units that could do "non-maneuver" or single location training may consider it for training.

BEN_O_{bumad} is the "benefit overall" for being able to train a certain unit in a specific division and is formed as a function of:

$LAND\_AVL_{ad}$ land available (also referred to as "land used") to train in MTA a division d (in square kilometers);

$LAND\_REQ_{bum}$ land required for battalion b's unit designation u to train for mission m.

Mathematically, BEN_O_{bumad} is represented as:

$$BEN\_O_{bumad} = \min[\ 1,\ \frac{LAND\_AVL_{ad}}{LAND\_REQ_{bum}}]$$

Within the model, the factor "MINLEVEL" controls BEN_O_{bumad}. For any particular run of the model, the ratio of land available to land required must be greater than or equal to this pre-determined minimum level. Thus:

$$MINLEVEL \leq \frac{LAND\_AVL_{ad}}{LAND\_REQ_{bum}}$$

MTA and mission combinations not meeting this condition results in $BENEFIT_{bumad}$ equalling zero.

2. A Value From Overtraining

The second group within the objective function accounts for units overtraining over the minimum requirements using variable $OVER_{buml}$. The model employs three levels of overtraining (although any number of levels is possible): low, medium and high. The overtraining variable has an upper bound of 1,3, or 5 (for "low", "medium", and "high", respectively) for all computational reports in this thesis. The placement of this variable into constraint (3) creates an upper bound on the number of iterations performed. The coefficient DE_VALUE_{bumadl} represents the amount taken away from the $BENEFIT_{bumad}$ value.

3. Below Minimum Iterations Required

The third and last group within the objective function is the penalty assessed when a unit fails to train its required level of iterations (MIN_REQ_{bum}). The decision variable DEV_MIN_{bum} captures any deviation and its coefficient DEV_PEN is the penalty assessed for failing to achieve minimum levels.

D. OBTAINING A FEASIBLE SCHEDULE

This study introduces a linear program that obtains a measure of military value for an installation's ability to support UMT. The solution to the linear program does not necessarily equate to a feasible training schedule. The linear program solution potentially allows a unit to train simultaneously in two or more divisions at the same time. However, it is possible to take the objective function value of the original solved linear program and produce an objective function value that does correspond to a feasible training schedule. In order to achieve these results, the following information is determined for each b,u,a,d combination (when $\sum_m X_{bumad} > 0$):

- The number corresponding to the days X_{bumad} needs to train,

- The number of days reserved (R_{bued}) for specific units in each division to train.

If the number of days needed for training exceeds the number of days reserved, then the objective function value associated with this amount of nonreservable training is removed from the objective function value.

IV. RESULTS FROM A TEST CASE - FORT HOOD, TEXAS

A. INTRODUCTION TO FORT HOOD, TEXAS

Fort Hood, Texas is chosen to exhibit the model's capabilities since it has new units arriving over the next five years [Ref. 8:p. 29] and it has all three types of Army units -combat, combat support, and combat service support. Additionally, the tables of requirements from TC 25-1 are applicable because the First Cavalry Division (1st CAV), currently home based at Fort Hood, is essentially a heavy mechanized division. Lastly, large training areas, convertible to MTAs for model purposes and thus classifiable into "GO", "SLOW-GO" and "NO-GO" terrain, exist at Fort Hood.

1. Fort Hood Based Units and Requirements

a. Current Inventory of Units

Figure 3 shows the major units currently stationed at Fort Hood [Ref. 9]. The majority of these units require maneuver land on which to practice required skills; thus, their inclusion into the model is necessary. Other units like the Headquarters III Corps and the Aviation Brigade (BDE), are not included in the study because these units have no requirements listed in TC 25-1.

For this thesis, units were modelled at battalion level and lower. This implies for example that a unit such as

Headquarters III Corps	Headquarters, 1st Cavalry (CAV) Division
Air Defense Artillery BDE Corps	1st BDE, 1st CAV
Aviation BDE Corps	2nd BDE, 1st CAV
Military Police BDE Corps	3rd BDE, 1st CAV
III Corps Support Command (COSCOM)	Engineer Regiment, 1st CAV
1st BDE, 5th ID	Division Artillery, 1st CAV
Division Support Command (DISCOM), 5th ID	Division Support Command (DISCOM), 1st CAV

Figure 3 Units Currently Stationed at Fort Hood. The battalions, companies and platoons that comprise these units are utilized in the formulation.

1st BDE, 1st CAV from Figure 3, would be dissected into battalion, company, and platoon levels. A brigade in a cavalry division has two types of basic maneuver battalions assigned to it. In order to model this, these two different types of battalions in the 1st BDE, 1st CAV are renamed as BN1 (for the one infantry battalion) and BN2 (for the two armor battalions). Since an infantry battalion has four maneuver (line) companies and one anti-armor company, company names such as C1 for the line company, and C2 for the anti-armor company are assigned. Finally, the identifier P1 is given to the three identical platoons in a line company and P2 is given to the next type of platoon. The model uses this convention for all of the remaining units in Figure 3. For Fort Hood, there are a total number of 22 distinct battalions. Appendix A lists all of the resultant battalion names and densities of battalions, companies and platoons.

b. Requirements for a Heavy Mechanized Division

Appendix A provides unit training requirements including each unit's required training missions, a specific size of a MTA required to perform needed missions, and a minimum number of iterations required to perform the mission.

2. Inventory of Training Land at Fort Hood

The training land at Fort Hood shown in Figure 4 is traditionally referred to and categorized as 65 separate training areas [Ref. 10:pp. B-2 - B-4]. Out of these 65, 8 are live fire areas while another 10 are impact areas. This study utilizes the 47 remaining training areas. Appendix B provides the size and a brief description of the these training areas. In order to develop "MTAs" as discussed in Chapter III, these 47 are grouped appropriately. Figure 5 shows how training areas are categorized into MTAs and indicates the initial and final size of the MTAs, as well as the number of possible divisions.

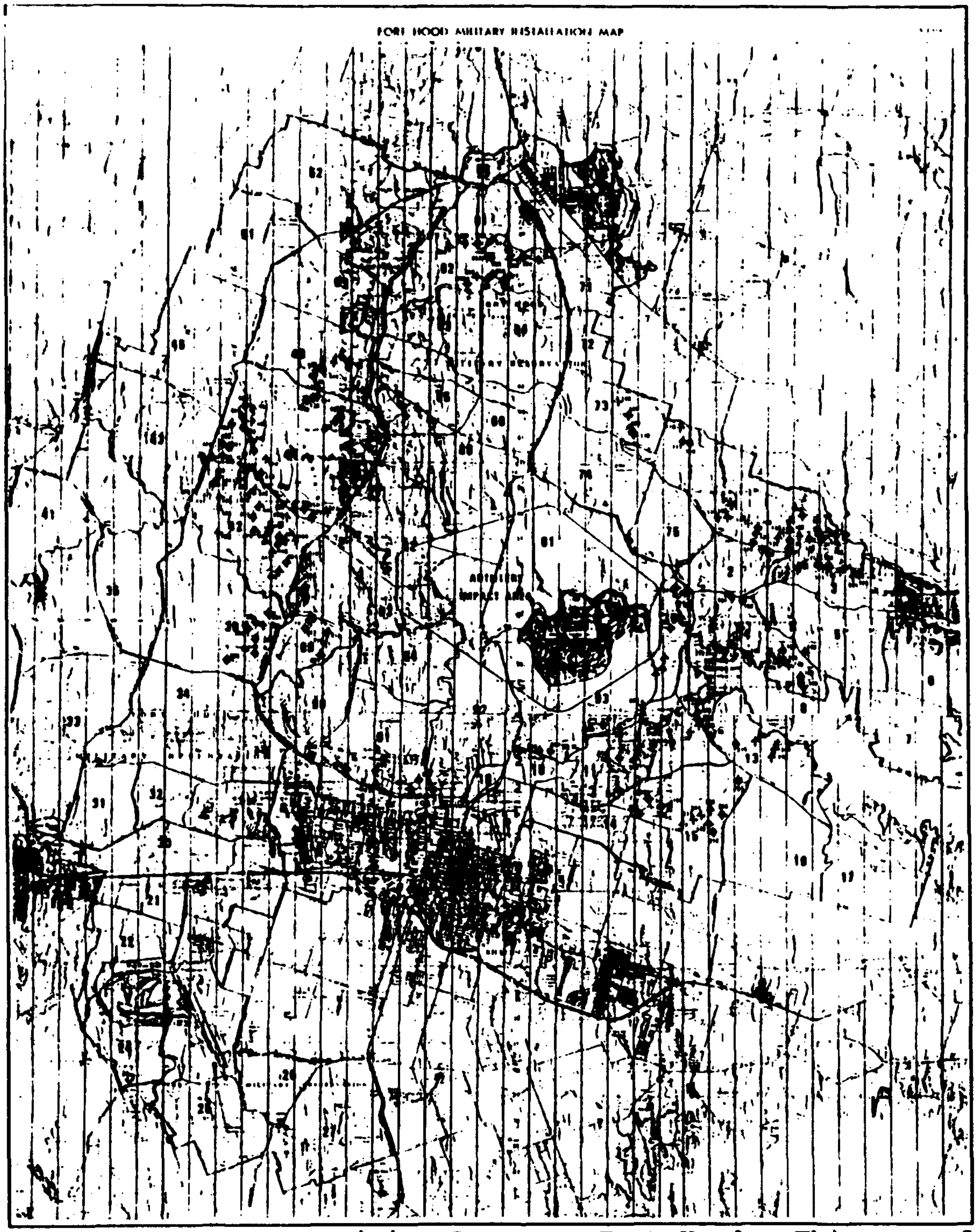

Figure 4 Current Training Areas at Fort Hood. This map of Fort Hood depicts all of the original training areas (bold numbers from approximately 1 through 77). This is before grouping into MTAs.

MAJOR TRAINING AREA (MTA)	ORIGINAL AREAS INCLUDED IN MTA	NUMBER OF POSSIBLE DIVISIONS	SIZE (SQ-KM)	FINAL SIZE EACH DIV	LAND CLASS.
MTA 1	30-36,41-45,48,51-54	28	280	10.00	GO
MTA 2	11-19	8	84.6	10.50	GO
MTA 3	25-27	4	36.6	9.16	SLOW-GO
MTA 4	1-7	9	88.5	9.80	SLOW-GO
MTA 5	21-24	4	24.7	6.17	SLOW-GO
MTA 6	71-73	4	17.7	4.41	SLOW-GO
MTA 7	8	4	9.89	2.47	SLOW-GO

Figure 5 Categorization of Fort Hood Training Areas. Training areas categorized into "MTAs" for use in the model. The last column indicates their classification with respect to maneuver training.

3. Benefit From Training

In order to reflect an appropriate training "benefit" specific to Fort Hood, the three parameters covering the type of unit, type of mission, and type of MTA the unit is assigned for training are specified.

a. Benefit From Training Certain Battalion's Units

Chapter II, Figure 3 shows the benefit value (BEN_BU_{bu}) used for unit types. Appendix A indicates the category of Fort Hood units related to these values.

b. Benefit From Specific Missions

To handle Fort Hood units' missions, the parameter BEN_BM_{bm} is normally established with a prioritization differentiating the different missions. However, none of the missions are given preference since a thorough knowledge of the 1st CAV's wartime mission is unknown.

c. Benefit From Specific MTAs

The last parameter, BEN_BMA_{bma}, is established for Fort Hood's battalion preferences and needs for specific types of terrain (remembering that each MTA is categorized by terrain) over other types. For example, Fort Hood Battalions 1 and 2 (BN1,BN2) benefit greatly from conducting UMT in MTAs 1,2 or 3 ("GO" terrain) versus the other four MTAs. Thus the associated BEN_BMA_{bma} for BN1 and BN2 is greater for MTA 1 or 2 than the other MTAs. Figure 6 shows the data used for BEN_BMA_{bma} for all computational work.

B. RESULTS

The General Algebraic Modelling System (GAMS) is used to generate the model [Ref. 11], and XA is used to solve the linear program [Ref. 12]. The model produces approximately 3,400 constraints, 19,000 variables and 29,000 non-zeros. All computational results are obtained using an AMDAHL 5995-700A dual processor mainframe computer in under 1 CPU minute.

The results of the test case are discussed in three parts. First the effect of varied land used/land required ratios on supporting UMT are shown. Second, other data such as the number of days that MTAs are available and the number of units existing at Fort Hood are adjusted to likely future levels. Third, results on how an objective function value for a "feasible" schedule is attained are discussed.

BATTALION DESIGNATION	M[illegible]NS	MTA 1	MTA 2	MTA 3	MTA 4	MTA 5	MTA 6	MTA 7
BN1	1,2,3,4,5,6,7	10	10	10	0	0	0	0
BN2	1,2,3,4,5,6,7	10	10	10	0	0	0	0
BN3-1	1,2,3	10	10	10	0	0	0	0
BN3-2	1,2,3	10	10	10	0	0	0	0
BN4	1	5	5	5	10	10	10	10
BN5	1	5	5	5	10	10	10	10
BN6	1,2,3	5	5	5	10	10	10	10
BN7-1	1	5	5	5	10	10	10	10
BN7-2	1	5	5	5	10	10	10	10
BN8	1,2,3	5	5	5	10	10	10	10
BN9	1	5	5	5	10	10	10	10
BN10-1	1,2,3,4,5	5	5	5	5	5	5	5
BN10-2	1,2	5	5	5	5	5	5	5
BN11	1,2,3,4	5	5	5	5	5	5	5
BN12	1,2,3,4,5,6,7	10	10	10	0	0	0	0
BN13	1,2,3,4,5,6,7	10	10	10	0	0	0	0
BN14	1	5	5	5	10	10	10	10
BN15	1,2,3,4,5	5	5	5	5	5	5	5
BN16-1	1,2,3	5	5	5	10	10	10	10
BN16-2	1,2,3	5	5	5	10	10	10	10
BN17	1,2,3	5	5	5	10	10	10	10
BN18	1,2,3,4,5	10	10	10	0	0	0	0

Figure 6 Parameter BEN_BMA_{bma} Used in the Model. For the battalions and training missions listed, a value for certain MTAs corresponds to the MTA supportability of this battalion's type of training.

1. Addressing Current Capabilities

One of the questions that this study answers is "what" is the current capability of Fort Hood to train their units with the current training areas (MTAs) available? The following statistics are presented:

- Percentage of required training performed,
- Percentage of training over required minimum levels,
- Percentage of days MTAs are used,
- Number of units training on 25%, 50%, 75%, 100% and over 100% of required land.

Most of the above issues are shown when the parameter "MINLEVEL" is decreased from 1.0 to 0.4 (recall that MINLEVEL = LAND USED/LAND REQUIRED).

a. Required Training Performed

At the current level of requirements for iterations, missions, and land size, only 84% of the required unit training iterations (UTI) are performed. In order to accomplish 100% of the required UTIs, the "MINLEVEL" parameter must be decreased to 0.4 (i.e., some units must train in land that is 40% of the required size). Figure 7 shows UTI percentages performed for varied MINLEVELs. Appendix C report C-8 shows how iterations performed are monitored for each of the units and reports C-1 and C-2 show summary results for MINLEVEL 1.0.

MINIMUM LEVEL OF LAND USED / LAND REQUIRED RATIO ALLOWED FOR MANEUVER TRAINING	NUMBER OF UNIT TRAINING ITERATIONS (UTI) PERFORMED	PERCENTAGE OF REQUIRED TRAINING
1.0	3717	84.04 %
0.9	3817	86.03 %
0.8	3925	88.74 %
0.7	4040	91.34 %
0.6	4221	95.43 %
0.5	4363	98.64 %
0.4	4423	100 %

Figure 7 Resulting Unit Training Iterations. UTIs performed at corresponding levels of "MINLEVEL". (MINLEVEL = Land Used/Land Required)

An alternate manner to view the results of Figure 7 is the number of UTIs that are not accomplished, or as addressed in the formulation, those "deviating from the minimum requirements." Figure 8 shows these results graphically.

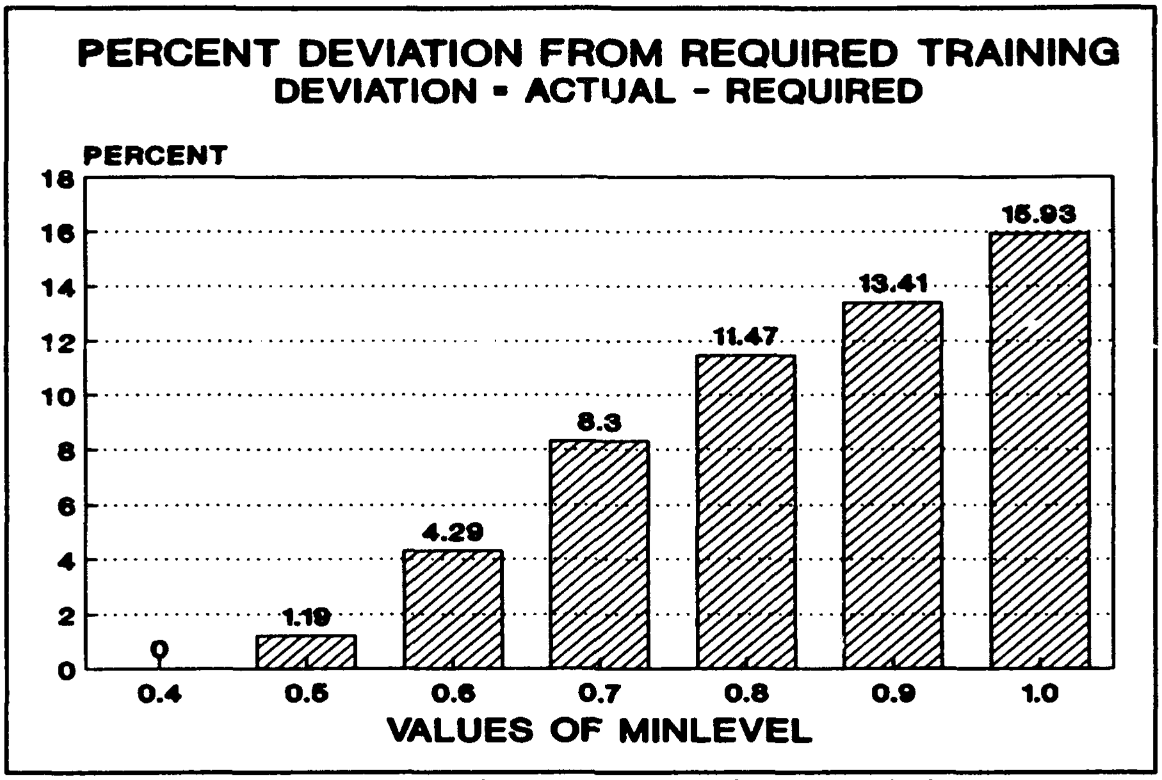

Figure 8 Percent Deviation From Required Training. As the settings for "MINLEVEL" are increased, there is a corresponding increase in the percent of deviation from the minimum required training.

b. Training Over the Minimum

As indicated in the discussion of the objective function, the model allows overtraining. Figure 9 indicates there is no significant overtraining being performed. Appendix C, reports C-3 through C-6 show actual data for MINLEVEL 1.0.

MINLEVEL	% LOW	% MEDIUM	% HIGH	% TOTAL
1.0	2.03	0.7	0.21	0.58
0.9	2.03	0.69	0.21	0.57
0.8	2.03	0.26	0.21	0.43
0.7	2.12	0.33	0.29	0.51
0.6	2.34	0.48	0.26	0.43
0.5	2.12	0.48	0.07	0.48
0.4	15.76	3.43	3.43	4.8

Figure 9 Overtraining Results. Figure 7 shows the three levels possible of overtraining and the associated percentage achieved. All percentages are equal to number performed divided by number possible.

c. Utilization Percentage For MTAs

The use of Fort Hood's MTAs for various MINLEVELs is shown in Figure 10. MTAs 1,2,3 and 4 are utilized 100% during all runs of the model. MTA 7 is actually a water training area, which few units require. Appendix C, report C-7 shows an example report for these data at MINLEVEL 1.0.

MINLEVEL:	0.4	0.5	0.6	0.7	0.8	0.9	1.0
MTA1	100	100	100	100	100	100	100
MTA2	100	100	100	100	100	100	100
MTA3	100	100	100	100	100	100	100
MTA4	100	100	100	100	100	100	100
MTA5	100	15.3	31.4	42.5	12.2	35.7	19
MTA6	1.1	0.3	18.9	11.9	1.2	1.1	8.9
MTA7	0.3	0	0	9.1	2.0	0.6	8.2

Figure 10 MTA Utilization Percentages. For each of the MTAs modelled, the percentage of days used to days available is shown. MTAs 1,2,3, and 4 are all preferred training MTAs.

d. Ratio of Land Used Within an MTA

An interesting power of the model is to examine the ratio of land used within an MTA that is assigned for unit maneuver training. Figure 11 displays these proportions for a run with "MINLEVEL" equal to 0.4.

MIN-LEVEL	Ratio (R) of land used per unit-mission:			
	$0.4 \le R < 0.5$	$0.5 \le R < 0.75$	$0.75 \le R < 1.0$	$1.0 \le R$
0.4	31.8 %	7.4 %	24.6 %	36.1 %

Figure 11 Percentages of Land Used/Land Required. Figure shows that of the units training, 31.8% are training with 40-50% of the amount of land actually required. Percentages are also shown for 3 other intervals.

2. Impact Of Other Parameters

a. Decreasing the Number of Training Days

Environmental issues could cause a decrease in the number of training days available. This situation is examined by decreasing the number of days all MTAs are available from 365 to 250 (approximately 30%). At MINLEVEL 1.0, the percentage of required training performed decreases to 75%. At a 0.4 MINLEVEL, there is virtually no difference with respect to percent UMT performed. However, there is a difference in the land used/land required ratio by units performing UTIs. Figure 12 shows the large increase in percentages of units training for their required missions on smaller land than required.

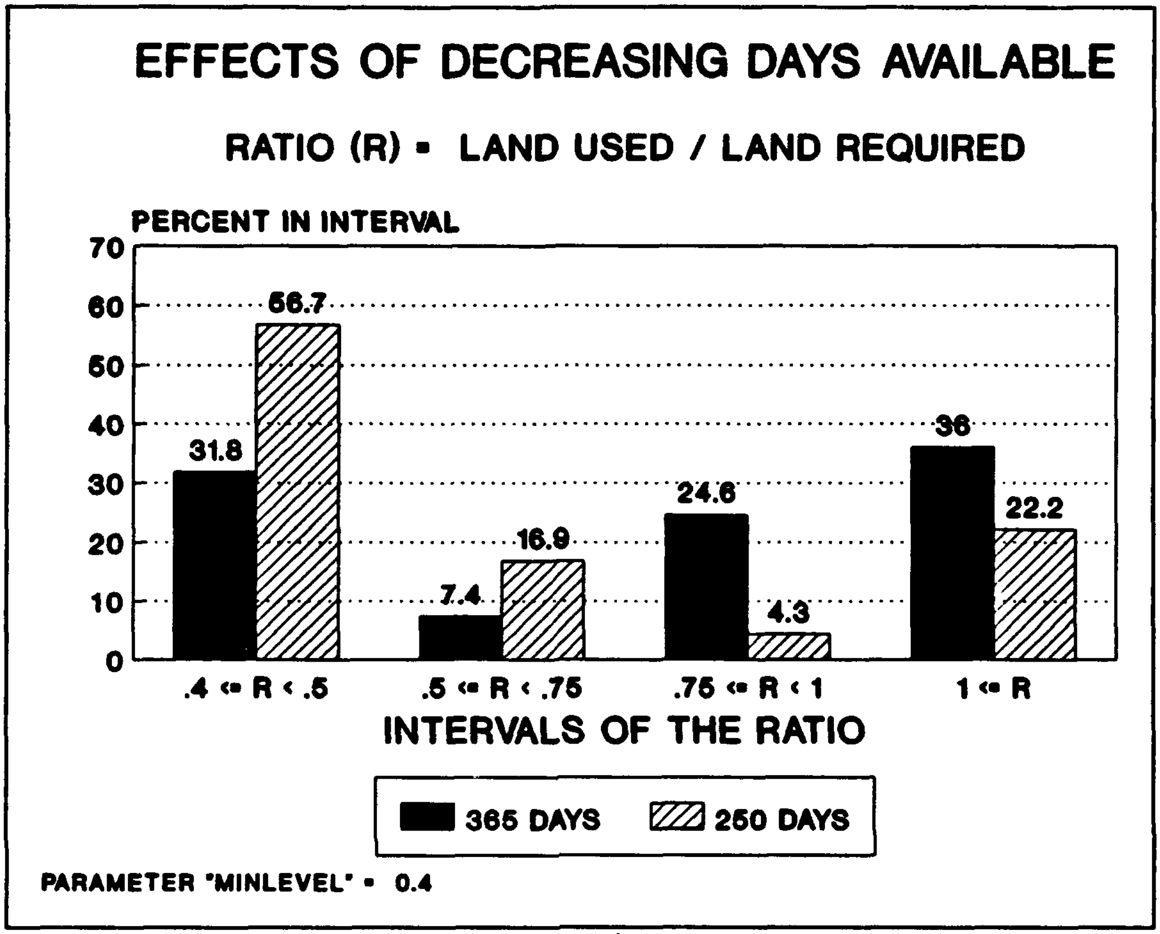

Figure 12 Ratio of Land Used/Land Required. There is a significant increase in the number of units training with less than 50% of the required amount of training land when the days available decreases from 365 to 250.

b. An Increase in the Number of Units

As recommended by the 1991 Base Realignment and Closure (BRAC) Committee, the 5th Infantry Division will relocate to Fort Hood by 1998[Ref. 8:p. 33] causing an increase in the number of stationed maneuver units. The increase will come primarily from the 2nd and 3rd Brigades, the Division Artillery (DIVARTY), the Engineers and the Division Support Command (DISCOM). With these units added to the current inventory at Fort Hood and at a MINLEVEL of 1.0, the percentage of required UTIs decreases from 84% to 75%.

3. Obtaining a Feasible Schedule

As discussed in Chapter III, an objective function value that corresponds to a "feasible" schedule can be attained from the linear program's objective function value. Figure 13 shows the percentage decrease in the linear program's objective function value corresponding to a feasible schedule for MINLEVELS 1.0, 0.9, 0.8, and 0.7. These percentages indicate that the linear program can not be easily converted to training schedules. Recall, it was not the purpose of the study to obtain a "schedule", only to obtain a measure of an installation's ability to support unit maneuver training.

MINLEVEL	PERCENTAGE WITHIN ORIGINAL OBJECTIVE FUNCTION VALUE
1.0	33.0%
0.9	66.5%
0.8	74.8%
0.7	130%
0.6	363%

Figure 13 Reaching an Objective Function Value for a Feasible Solution. Percentages are after unobtainable training iterations have been removed. Percent is within the original objective function value.

V. CONCLUSION

The linear program this thesis develops can assist the Army in measuring the ability of its installations to support unit maneuver training. The linear program demonstrates its ability using Fort Hood, Texas. Using the current sizes of training areas, iterations, and days per iteration required, the model's results indicate that only 84% of all unit maneuver training can be supported by Fort Hood. In order to train to the full 100% of all required unit training iterations, the ratio of land size used to land size required must be decreased to 0.4. This implies that some units are forced to train in areas with less than half of the amount of training area they need to become proficient in their required tasks.

The model also indicates the percentage of the units performing unit maneuver training with various sizes of the training areas. At a minimum acceptable ratio of land used to land required (MINLEVEL) of 0.4 and 365 day availability of the training areas, approximately 32% of units use between 40% and 50% (MINLEVEL at 0.4 to 0.5) of the Army doctrine required amount; while 36% of the units use 100% (MINLEVEL at 1.0) or over the required amount.

When the current level of units is increased to the projected 1998 level, the level of required unit training iterations performed drops to 75%. Additionally, the same decrease is achieved when the number of days that the training areas are available is decreased because of environmental considerations. For both of these scenarios, the MINLEVEL was set at 1.0.

This test case demonstrates the model can be helpful to the Army in its efforts to determine which CONUS installations to realign or CONUS units to relocate based upon maneuver training criteria.

This model could be used in conjunction with Army models designed to quantify the overall training ability of Army installations or in combination with other models that consider all of the requirements placed upon Army units.

Because there is currently a great deal of attention given to spending on defense, the Army continues to research ways to maintain its proficiency with the resources they have available. The focus of this thesis has been solely on the resources related to unit maneuver training; thus combining this study with models that emphasize other unit requirements such as live-fire training or station support requirements may produce a more accurate "military value" for Army installations. An optimization model that combines all of these requirements together with the available assets of a given installation would be quite valuable.

APPENDIX A: TRAINING CIRCULAR 25-1 REQUIREMENTS

(1) UNIT TYPE: BN: BATTALION CO: COMPANY PLT: PLATOON	(2) QUANTITY OF	(3) MISSION NAME:	(4) LAND REQ (SQ-KM)	(5) MIN REQ	(6) DAY REQ
MECHANIZED (MECH) INFANTRY (IN) BN ARMOR (AR) BN [CBT]	5 8	Movement to Contact	248	4	1
		Offensive Operations (Opns)	68	4	1
		Defensive Opns	138		
		Retrograde	138		
MECH INFANTRY CO [CBT]	20	Movement to Contact	84	3	1
		Attack	50	3	1
		Raid	50	3	2
		Ambush	50	3	2
		Defend	24	3	2
		Retrograde	102	3	2
		Reconnaissance and Surveillance	78	3	2
ARMOR CO [CBT]	32	Movement to Contact	30	3	1
		Offense	15.8	3	1
		Raid	15.8	3	1
		Defend	3	3	1
		Retrograde	24	3	1
		Reconnaissance and Surveillance	16	3	1
MECH IN PLT [CBT]	60	Movement to Contact	24	4	2
		Attack	18	4	2
		Raid	18	4	2

(1) UNIT TYPE: BN: BATTALION CO: COMPANY PLT: PLATOON	(2) QUANTITY OF	(3) MISSION NAME:	(4) LAND REQ (SQ-KM)	(5) MIN REQ	(6) DAY REQ
		Ambush	30	4	2
		Defend	30	4	2
		Retrograde	50	4	2
		Reconnaissance and Surveillance	21	4	2
ARMOR PLT [CBT]	96	Attack	3	3	1
		Defend	0.32	3	1
Anti-Tank CO/PLT [CBT]	4	Provide Direct Anti-Tank (AT) Fire	60	3	1
Mortar PLT [CBT]	12	Provide Indirect Fire Support (OFF)	60	2	1
		Provide Indirect Fire Support (DEF)	28	2	1
Scout PLT [CBT]	12	Security Opns	135	4	1
		Recon Opns	135	4	1
Support PLT [CBT]	12	Provide Logistics Support (Spt)	20	3	1
Medical PLT [CBT]	12	Provide Health Spt	8	3	1
Maintenance PLT [CBT]	12	Provide Maintenance Spt	4.5	3	1
		Conduct Recovery Opns	4.5	3	1
Communications PLT [CBT]	12	Provide Communications Spt to Control Post	1	3	1

(1) UNIT TYPE: BN: BATTALION CO: COMPANY PLT: PLATOON	(2) QUANTITY OF	(3) MISSION NAME:	(4) LAND REQ (SQ-KM)	(5) MIN REQ	(6) DAY REQ
Vulcan PLT [CS]	18	Air Defense Artillery (ADA): Static vs Low Altitude (LA) Hostile Target (TGT)	25	2	1
		ADA:Static vs LA Mobile TGT	8	2	1
		ADA:Mobile vs LA Hostile TGT	25	2	1
Stinger PLT [CS]	8	ADA:Static vs LA Hostile TGT	25	2	1
		ADA:Static vs LA Mobile TGT	8	2	1
		ADA:Mobile vs LA Hostile TGT	25	2	1
Field Artillery (FA) BN 155 Millimeter (mm) Self-Propelled (SP) [CBT]	3	Fire Spt Opns	270	4	2
FA Headquarters and Headquarters' Battery (HHB) 155 mm (SP) [CBT]	3	Tactical Opns	6	4	2
Service Battery (BTY) 155 mm (SP) [CBT]	3	Tactical Opns	6	4	2
	9	Provide Fire Spt	48	4	2
FA BTY Multiple Rocket Launching System (MLRS) [CBT]	1	Tactical Opns	48	4	2
FA PLT, MLRS [CBT]	3	Provide Fire Spt	9	4	2

(1) UNIT TYPE: BN: BATTALION CO: COMPANY PLT: PLATOON	(2) QUANTITY OF	(3) MISSION NAME:	(4) LAND REQ (SQ-KM)	(5) MIN REQ	(6) DAY REQ
CBT Military Police (MP) CO [CS]	5	Area Security	144	2	1
		Battlefield Control	144	2	1
		Enemy Prisoners of War (EPW)	4	2	1
Main Spt BN [CSS]	2	Tactical Opns	49	4	1
Forward Spt BN [CSS]	4	Tac Opns	120	4	1
Military Intelligence CO [CSS]	1	Establish BN Trains	16	4	1
		Establish Tactical Opns	1.5	4	1
Collection and Jamming CO [CSS]	1	Provide Signal Intelligence/Early Warning (SIGINT/EW)	33	4	1
EW CO [CSS]	1	Provide SIGINT/EW	50	4	1
Intelligence and Surveillance CO [CSS]	1	Provide Ground Surveillance Radar (GSR) Spt	30	4	1
		Conduct Interrogation Opns	1	4	1
		Conduct Counter Intelligence Opns	1	4	1
Long Range Surveillance Detachment [CSS]	1	Provide Surveillance Spt	6	4	1

(1) UNIT TYPE: BN: BATTALION CO: COMPANY PLT: PLATOON	(2) QUANTITY OF	(3) MISSION NAME:	(4) LAND REQ (SQ-KM)	(5) MIN REQ	(6) DAY REQ
Division Signal BN [CS]	1	Not Listed	0.15	5	5
Engineer CO [CS]	8	Mobility	196	2	1
		Countermobility	196	2	1
		Survivability	196	2	1
		Sustainment	196	2	1
		Fight as Infantry	196	2	1
Engineer PLT [CS]	24	Mobility	196	2	1
		Countermobility	196	2	1
		Survivability	196	2	1
		Sustainment	196	2	1
		Fight as Infantry	196	2	1
Engineer CO Bridge [CS]	1	Conduct Fixed Bridge Opns	196	2	1
		Conduct Float Bridge Opns	196	2	1
Engineer PLT Bridge [CS]	3	Conduct Fixed Bridge Opns	196	2	1
		Conduct Float Bridge Opns	196	2	1
NBC Reconnaissance (Recon) PLT [CSS]	1	Conduct NBC Recon	10	4	1
		Conduct NBC Surveillance	20	4	1
		Conduct Recon	25	4	1
Decontamination (Decon) PLT [CSS]	4	Operate Personnel Decon	3	4	1

(1) UNIT TYPE: BN: BATTALION CO: COMPANY PLT: PLATOON	(2) QUANTITY OF	(3) MISSION NAME:	(4) LAND REQ (SQ-KM)	(5) MIN REQ	(6) DAY REQ
		Operate Hasty Decon (12 hour)	9	4	1
		Operate Hasty Decon(24 hour)	3	4	1
Smoke Generating PLT [CSS]	1	Provide Long Duration Smoke	100	4	1
		Conceal River Crossing	25	4	1
		Conceal a Moving Force	126	4	1
		Conceal a Breach Opn	25	4	1

Notes:

1. Column 1 represents all of the different units at Fort Hood. In order to get the battalion number (e.g., BN1, BN2, etc.) simply number different battalions starting at the top of the table. Column 1 also gives the indication of the category of battalion to which the unit belongs. The abbreviation found in this column in hard brackets (ie. "[CBT]") indicates the category.

2. Column 2 gives density of the unit types at Fort Hood. Where common units exists, these numbers may represent multiple units (e.g., two separate battalions or divisions).

3. Column 3 provides individual missions for each unit. The naming convention for the model formulated these as MISSION1, MISSION2, etc., for each of the units.

APPENDIX B: Inventory and Descriptions of Training Areas

Training Areas at Fort Hood:

TRNG AREA	# OF ACRES	# OF SQ-KM	MTA	REMARKS:
1	4940	20.00	4	Hilly, rugged terrain with dense vegetation. Platoon and company size dismounted training. Excellent for scouting and patrolling.
2	1478	5.98		
3	3373	13.66		
4	2390	9.68		Cross-country mechanized infantry training. Armor and Infantry teams training. Limited task force training.
5	3359	13.60		Hilly, rugged terrain with dense vegetation. Platoon and company size dismounted training. Excellent for scouting and patrolling.
6	3077	12.46		
7	3260	13.20		
8	2444	9.89	7	Used for engineer and amphibious training for fixed locations by combat support and combat service units. Located on civil works (Belton Reservoir) -- land permitted to Fort Hood.
11	1878	7.60	2	Cross-country mechanized infantry training. Armor and Infantry teams training. Limited task force training.
12	2223	9.00		
13	2160	8.74		
14	2184	8.84		Phantom Run Crew Commander's Proficiency Course (CCPC)
15	3826	15.49		Real Train Exercise and mounted tactical training.
16	6224	25.20		Used for signal site, TCPC course, and small unit training area.
17	1508	6.11		
18	655	2.65		
19	247	1.00		Soldier's qualification test training area.
21	1250	5.06	5	Close-in Training Area for Corps Support Command.
22	1659	6.72		
23	967	3.92		Small Unit Training, Expert Infantry Badge Testing.
24	2220	8.99		Training Area for 504th MI BDE.

TRNG AREA	# OF ACRES	# OF SQ-KM	MTA	REMARKS:
25	3161	12.80	3	III CORPS NCO Academy
26	1442	5.84		
27	4446	18.00		
30a	1002	4.06	1	Close-in Training Area for 31st ADA BDE.
30b	1002	4.06		Close-in Training Area for Corps Support Command.
31	1778	7.20		Cross-country armored and mechanized infantry terrain. Task Force Level tactical exercises. Emergency deployment readiness exercises (EDRE). Three drop zones and one dirt landing strip.
32	1319	5.34		
33	6267	25.37		
34	6309	25.54		
35	6932	28.06		
36	5407	21.89		
41	4752	19.24		
42	3823	15.48		
43	4286	17.35		
44	6291	25.47		
45	4328	17.52		
48	2821	11.42		
51	2781	11.26		
52	4549	18.42		
53	4802	19.44		
54	596	2.41		
71	1604	6.49	6	Hilly, rugged terrain with dense vegetation. Individual and platoon dismounted infantry training. Expert Infantry Badge testing area, patrol training area, and locations for command post exercises.
72	929	3.76		
73	1829	7.40		

Note:
Dashed lines separating the groups of training areas represent the major training areas as formulated in the model introduced in this thesis.

APPENDIX C: REPORTS SHOWING TRAINING FREQUENCY DATA:

REPORT C-1 SUMMARY; FREQUENCY OF UNIT TRAINING

1.) Results show total quantity of iterations for each of the categories of possible training.

2.) REQUIRED = AT MINIMUM + BELOW MINIMUM + DEVIATIONS.

(1) TOTAL AT MIN	(2) OVER LOW	(3) MEDIUM	(4) TOTAL HIGH	(5) OVER	(6) DEV	(7) REQ
3717	85	88	45	218	705	4423

REPORT C-2 SUMMARY; PERCENTAGES OF UNIT TRAINING FREQUENCY

1.) Results show total quantities and percentages of training that is performed at the none, over-low,medium and high categories.

2.) All quantities shown are based on actual numbers of units and their required iterations.

(1) # NOT TRAINED	(2) PCT NONE	(3) BELOW MIN	(4) PCT BELOW	(5) AT MIN	(6) PCT AT	(7) OVER MIN	(8) PCT OVER	(9) SUM UTI
705	15.93	1	0.03	3717	84.04	218	4.92	4423

REPORTS SHOWING "OVER" TRAINING LEVEL DATA:

REPORT C-3 SUMMARY; STATUS OF "LOW" LEVEL TRAINING

1.) This is provided to show the maximum number of {LOW} iterations over the maximum that could be performed.

2.) The percentages then represent the number that were performed divided by the number possible (3) and then those performed with respect to the total number of over training (4) and the total number of any iterations (5).

3.) LOW UNIT TRAINING ITERATIONS(LUTI) POSSIBLE:

```
LUTI =
(OVER_LO.UP(B,U,M) *  UD(BSU) ) for all B,U,M;
```

(1) LOW UNIT TRAINING ITERATIONS POSSIBLE	(2) TOTAL LOW ITERATIONS ACTUALLY PERFORMED	(3) PERCENTAGE OF LOW PERFORMED TO LOW POSS	(4) PERCENTAGE OF LOW PERF TO TOTAL OVER PERF	(5) PERCENTAGE OF LOW PERF TO TOTAL AT MINIMUM
4194	85	2.03	39.08	2.29

REPORT C-4 SUMMARY; STATUS OF "MEDIUM" LEVEL (OVER) TRAINING

1.) This is provided to show the maximum number of {MED} iterations over the maximum that could be performed.

2.) The percentages then represent the number that were performed divided by the total number possible(3) than those performed with respect to the tota number of over training (4) and the total number of regular iterations (5).

3.) MEDIUM UNIT TRAINING ITERATIONS(MUTI) POSSIBLE:

```
MUTI =
(OVER_MED.UP(B,U,M) *  UD(BU)))  for all B,U,M;
```

(1) MEDIUM UNIT TRNG ITERATIONS POSSIBLE	(2) TOTAL MED ITERATIONS ACTUALLY PERFORMED	(3) PERCENTAGE OF MED PERFORMED TO MED POSS	(4) PERCENTAGE OF MED PERF TO TOTAL OVER PERF	(5) PERCENTAGE OF MED PERF TO TOTAL AT MINIMUM
12582	88	0.70	40.23	2.35

REPORT C-5 SUMMARY; STATUS OF "HIGH" LEVEL (OVER) TRAINING

1.) This is provided to show the maximum number of {HIGH} iterations over the maximum that could be performed.

2.) The percentages then represent the number that were performed divided by the total number possible(3) then those performed with respect to the total number of over training (4) and the total number of regular iterations (5).

3.) HIGH UNIT TRAINING ITERATIONS(HUTI) POSSIBLE:

```
HUTI =
(OVER_HI.UP(B,U,M) *  UD(BU)))  for all B,U,M;
```

(1) HIGH UNIT TRAINING ITERATIONS POSSIBLE	(2) TOTAL HIGH ITERATIONS ACTUALLY PERFORMED	(3) PERCENTAGE OF HIGH PERFORMED TO HI POSS	(4) PERCENTAGE OF HI PERF TO TOTAL OVER PERF	(5) PERCENTAGE OF HI PERF TO TOTAL AT MINIMUM
20970	45	0.21	20.69	1.21

REPORT C-6 SUMMARY; STATUS OF TOTAL "OVER" TRAINING

1.) This is provided to show the maximum number of TOTAL {OVER} iterations over the maximum that could be performed.

2.) The percentages then represent the number that were performed divided by the total number possible(3) then those performed with respect to the total number of ALL training (4).

(1) OVER UNIT TRAINING ITERATIONS POSSIBLE	(2) TOTAL OVER ITERATIONS ACTUALLY PERFORMED	(3) PERCENTAGE OVER PERF TO TOTAL OVER POSS	(4) PERCENTAGE OF OVER PERF TO TOTAL PERF AT MINIMUM
37746	218	0.58	5.85

REPORT ON LAND USAGE:

REPORT C-7 SUMMARY; STATUS OF MAJOR TRAINING AREA USAGE

1.) Each MTA was actually used (PERCENTAGE = DAYS USED/DAYS AVAILABLE).

2.) These figures are for MINLEVEL of 1.0.

(1) AREA	(2) PERCENTAGE DAYS USED	(3) SIZE OF AREA WHEN WHOLE
MTA1	100.00	280
MTA2	100.00	85
MTA3	100.00	37
MTA4	100.00	89
MTA5	18.84	25
MTA6	8.95	18
MTA7	8.22	10

REPORT ON SPECIFIC BATTALION'S ITERATIONS PERFORMED:

REPORT C-8 SUMMARY; ITERATIONS PERFORMED

1.) Results show total iterations performed by a battalion's units on their required missions.

2.) Percentage(COLUMN 6) is the number performed/number required.

(1) BATTALION DESIGNATION	(2) UNIT	(3) MISSION	(4) # ITERATIONS PERFORMED	(5) NUMBER REQUIRED	(6) PERCENT OF REQUIRED
BN1	B	MSSN1	0	12	0
BN1	B	MSSN2	12	12	100
BN1	B	MSSN3	0	12	0
BN1	B	MSSN4	0	12	0
BN1	C1	MSSN1	36	36	100
BN1	C1	MSSN2	36	36	100
BN1	C1	MSSN3	36	36	100
BN1	C1	MSSN4	36	36	100
BN1	C1	MSSN5	36	36	100
BN1	C1	MSSN6	0	36	0
BN1	C1	MSSN7	0	36	0
BN1	C2	MSSN1	12	12	100
BN1	P1	MSSN1	144	144	100
BN1	P1	MSSN2	144	144	100
BN1	P1	MSSN3	144	144	100
BN1	P1	MSSN4	144	144	100
BN1	P1	MSSN5	144	144	100
BN1	P1	MSSN6	144	144	100
BN1	P1	MSSN7	144	144	100
BN1	P2	MSSN1	6	6	100
BN1	P3	MSSN1	12	12	100
BN1	P3	MSSN2	0	12	0
BN1	P4	MSSN1	9	9	100
BN1	P5	MSSN1	9	9	100
BN1	P6	MSSN1	9	9	100
BN1	P6	MSSN2	9	9	100
BN1	P7	MSSN1	9	9	100
BN2	B	MSSN1	0	24	0
BN2	B	MSSN2	24	24	100
BN2	B	MSSN3	0	24	0
BN2	B	MSSN4	0	24	0
BN2	C1	MSSN1	72	72	100
BN2	C1	MSSN2	72	72	100
BN2	C1	MSSN3	72	72	100
BN2	C1	MSSN4	72	72	100
BN2	C1	MSSN5	72	72	100
BN2	C1	MSSN6	72	72	100

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